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Original Research

The effect of coronary artery bypass grafting procedure on audiovestibular system

Coronary bypass and audiovestibular system

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Abstract

Aim: Coronary artery bypass grafting surgery may affect end-organ perfusion. Our aim was to examine the effect of this method on audiovestibular system.

Material and Methods: Patients who had CABG were called and invited. Pure tone audiometric test, c- and o-VEMP tests were performed for all participants.

Results: The results at 250, 500, 2000 and 4000 Hz differed for the left ears (p=0,013, p=0,045, p=0,028, p=0,045) and in the right ears, p13 (p = 0.040) were differentiated among the groups and the p13-n23 amplitude was lower in the bypass group (p=0,013). In the left ear results , p13-n23 amplitude (p= 0.007) and n10-p15 amplitudes (p = 0.006) differed between the groups, and the right ear n10-p15 amplitudes were lower in the bypass group (p = 0,005). Mean n10 (p=0,006) and p15 latency were high in the bypass patients (p= 0,005).

Discussion: CBAG may affect balance-connected mechanisms at varied levels and intensity.

Keywords

Coronary Artery Bypass Grafting, Vestibular Evoked Myogenic Potentials, c-VEMP, o-VEMP, Audiovestibular

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Introduction

Coronary artery bypass grafting (CABG) is a surgical method that the great majority of patients experience to obtain a better quality of life despite critical risks including cardiac ischemia 3.9 %, stroke 1.3 % and even death 1.7 % [1]. It can be assumed that many factors influence the change in end-organ failure following postcardiac surgery with CABG. Systemic inflammatory reply, conversion from a dynamic flux to a static flux in the CABG course, hypoperfusion, microemboli, reperfusion and ischemia are the most significant factors. Cardiac surgical procedures provoke SIR (systemic inflammatory response). SIR is activated by various factors, including the induction of inflammatory cytokines, coagulation, complement, fibrinolysis and cytodevastating mediators emerged by white blood cells. The initiation of anesthesia and following CABG induce severe alterations at the stage of the microcirculation. Following induction, the number of perfused capillaries decreases to 70 %, and after the start of CABG, it decreases to nearly 53 %. When emboli are restricted in an organ, smaller capillary and arterial expansions are monitored in the organ [2]. It is thought that the off-pump coronary bypass grafting procedure causes less oxidative damage with no cardioplegic arrest and the continuation of normothermia [3,4]. Prior results of on-pump cardiac surgical cases demonstrate a greater level of oxidative stress in comparison to cases undergoing off-pump cardiac surgical procedures [5-8]. For this reason, we decided to analyze the effect of on-pump CABG on audiovestibuler system.

Sudden sensorineural hearing loss (SSNHL) is an infrequent pathology following cardiological surgical procedure with extracorporal cycle and has been indicated in past studies [9]. The rate of SSNHL following cardiac surgery with extracorporal circulation (CSWEC) has been declared to be 0.1 % [9-11]. Shapiro et al. reported two cases of unilateral serious SSNHL following cardiac surgical procedure with extracorporal circulation [11].

Balance association is an important task to maintain a normal life, and is achieved in the centrical nervous system based on the data released from ocular, vestibular, and as well as proprioceptive mechanisms. Vestibular-evoked myogenic potentials (VEMP) provide for the evaluation of task and entirety of vestibular routes in the brainstem and assessment and evaluation of central pathologies. Cervical VEMP (c-VEMP) can be detected via sternocleidomastoid muscle and indicates an inhibitor vestibulo-collic reflex as a reaction to an acoustic stimulant. The test represents the functionality of the ipsilaterally inferior vestibular nerve and saccule. Additionally, ocular VEMPs (o-VEMP) can be detected via the inferior oblique muscle and demonstrate the vestibulo-ocular reflex as an action on an acoustic stimulant, and the test represents the functional status of the contralateral superior vestibular nerve as well as utricle [12].

While preparing this article, we did not find any research in the literature examining the evaluation of the vestibular system after on-pump CABG. We decided to evaluate the vestibular system in patients who had undergone on-pump CABG with cervical (c-VEMP) and ocular VEMP (o-VEMP) test batteries.

Material and Methods

Study Design

The study was performed at Malatya Training and Research Hospital, Otorhinolaryngology Department between September and December 2021. Ethical approval was obtained from the Clinical Research Ethics Committee of Turgut Ozal University (ethical approval number 2021/40). In the research, our goal was to determine the vestibular functionality of cases who had previously undergone on-pump CABG with pure tone audiometry, oVEMP and cVEMP tests. Following the ethics committee approval, the patients who had on-pump CABG were identified from the information system of our hospital, they were called by phone and invited to our clinic for ENT examination. All participants underwent a complete ENT examination. We included patients younger than 60 years of age in our research to prevent the effects of aging on VEMP results, and the control group consisted of patients of the same age group. Patients with previous ear surgery, hearing loss, Meniere's disease, chronic diseases such as diabetes mellitus that may affect the vestibular system and our test results, patients receiving vestibulo-suppressant treatment, previous COVID-19, patients with herpes simplex and herpes zoster were excluded from the study. A detailed anamnesis was taken following the ENT examination of the patients. Demographics of the participants were noted. All participants underwent the Dix-Hallpike test, pure tone audiometric evaluation, c- and o-VEMP tests. The control group was formed from patients with similar demographic characteristics who applied to the ENT outpatient clinic for other reasons and were accepted to participate in the research. Audiometric measurements were carried out via Interacoustics AC40 apparatus (Middelfart, Denmark) to determine six distinct frequencies (250 Hz, 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz, and 8000 Hz) in an appropriate quiet test cabin.

Cervical VEMP test

The cervical VEMP (c-VEMP) test was carried out via Interacoustics Eclipse EP25 (Middelfart, Denmark). Tone-burst stimuli were applied to the ear via IP30 insert earphones (RadioEar, Middelfart, Denmark). Tone-burst stimuli (105 dB nHL, 500 Hz, each featured as a 2-ms rising decline and a 0-ms plateau period, stimulus density 5.1/second) were given to each ear. Electromyography (EMG) signals were expanded and the bandpass was set between 30 and 2000 Hz frequencies. c-VEMP tests were carried out between 100 microvolts (μV) root mean square (RMS) and 150 μV RMS. Interpeak latencies, peak and peak-to-peak amplitudes of the p13 and n23 waves were recorded individually for each ear. The asymmetry rate was calculated using the formula described by Murofushi et al. (Asymmetry rate: 100 (Au-Aa) / (Au + Aa) Au: p13 – n23 (the peak-to-peak amplitude of the unaffected side), Aa: p13 – n23 (the peak-to-peak amplitude of the affected side) between the left and right ear [13]. In accordance with normal data of the present study, an asymmetry rate of greater than 19 % was settled as anomalous and agreed as a sign of saccular defect on the side demonstrating a falling amplitude reply.

Ocular VEMP test

The o-VEMP test was achieved via an Interacoustics Eclipse EP25 apparatus (Middelfart, Denmark). The EMG signals were expanded and bandpass-set among 1 and 1000 Hz frequencies. The sound stimulus was applied to the contralateral part of the effective electrode with a density of 105 dB nHL. The peak latencies and peak-to-peak amplitudes of the n10 and p15 waves were recorded for each ear. The asymmetry rate was calculated adhering to the formula described by Murofushi et al. [13]. Based on our normal data, we approved asymmetry ratios of more than 28 %, as the asymmetry was presented among the two ears and has been recognized as a sign of utricular pathology on the side demonstrating a decreased amplitude reply.

Data examination was performed by utilizing the IBM SPSS version 26.0 statistical program (Chicago, IL, USA). Skewness and Kurtosis values were utilized to measure the normality of the data dispersion. Demonstrative statistical data were specified as mean, standard deviation, median, range and quartile difference (Q1-Q3) for quantitative variables. The analysis of non-normally distributed groups was carried out with the Mann-Whitney U test, and the analysis of normally-distributed groups was carried out with the Independent Sample T-test. A Two-Way Repeated ANOVA analysis was utilized to examine significance among the experimentals and controls with repetitive measurements. A p-value of <0.05 was agreed to show numerical significance [14].

Ethical Approval

Ethics Committee approval for the study was obtained.

Results

A total of 61 participants, 31 patients and 30 controls were included in our study. The demographic data were similar for the two groups. The mean age was 48,34±5,39 for controls and 49,47±5,71 for the bypass group. In the patient group, the least time passed since bypass surgery was on the 13th postoperative month, and the longest duration was 8 years.

In audiologic assessment, while all frequencies were detected in normal ratio, a numerical significance was determined at 250 (p= 0,013), 500 (p=0,045), 2000 (p=0,028) and 4000 (p=0,045) Hz for left ears in the comparison between the groups (Table1). When both the left and right ears were evaluated, numerical significance was detected at 250 (p=0,016) and 4000 Hz (p=0,025). Mean values were higher in the bypass group for all frequencies (Table 1). When the right ears were compared, no difference was observed in any frequencies between the two groups (Table 1).

The c- and o-VEMP replies could be gained in all participants of the control group. In the bypass group, we could not obtain o-VEMP bilaterally in 4 patients and unilaterally in 4 patients from a total of 12 ears (12.9%). In the bypass group, c-VEMP responses could not be obtained bilaterally in 2 patients and unilaterally in 2 patients (6.4%). In the cVEMP test, the values of p13 latency, n13 latency, p13-n23 latency, and the p13-n23 amplitude were evaluated for both the right and left ears and analyzed between bypass and control groups. According to the outcomes of the right ear cVEMP, the latency of p13 (p = 0.040) was prominently differentiated among the two groups. The average p13 latency was 17,85±5,27 ms for the bypass group and the p13 latency was greater than the controls. Mean p13-n23 amplitude was detected as 73,77±54,43 mv in bypass

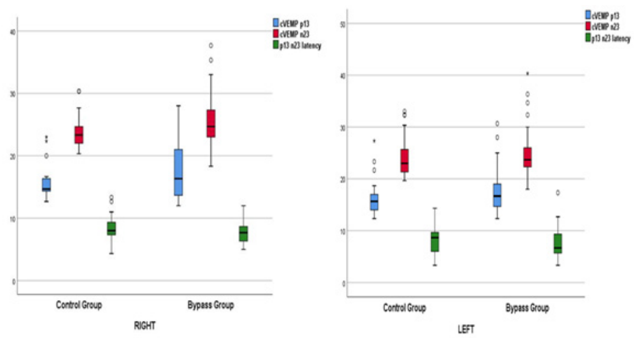

Figure 1. Comparison of p13, n23 and p13-n23 latency values of the right and left ears between bypass and control group.

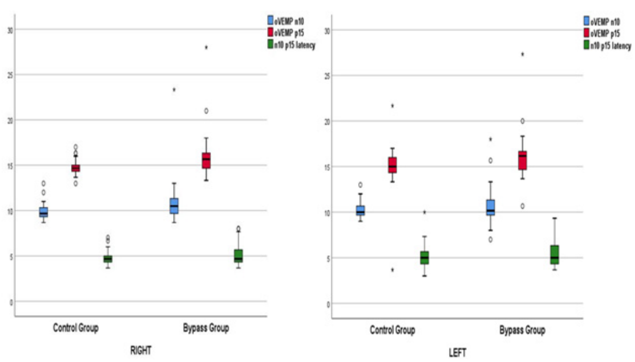

Figure 2. Comparison of right and left ears results of the n10, p15 and n10-p15 latency values between bypass and control group.

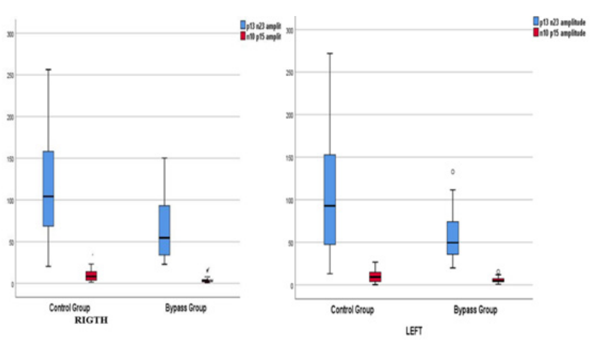

Figure 3. Comparison of right and left ears results of the p13-n23 and n10-p15 amplitude values between bypass and control group.

Table 1. Audiologic results of control and bypass group.

LEFT	Control Group		Bypass Group		P value
	Mean±SD	Median (range) (Q1-Q3)	Mean±SD	Median (range) (Q1-Q3)	
250 Hz	12,76±4,137	10,00(15)(10,00-15,00)	16,56±7,007	15,00 (30)(10,00-20,00)	0,013
500 Hz	12,76±4,549	10,00 (15)(10,00-15,00)	14,84±5,887	15,00 (30)(10,00-15,00)	0,045
1000 Hz	11,03±5,241	10,00 (15)(5,00-15,00)	14,53±5,137	15,00 (15)(10,00-15,00)	0,247
2000 Hz	12,59±5,281	10,00 (20)(10,00-15,00)	14,06±5,599	15,00 (25)(10,00-15,00)	0,045
4000 Hz	15,86±6,418	15,00 (30)(10,00-20,00)	20,78±6,733	20,00 (25)(15,00-25,00)	0,028
8000 Hz	13,62±7,183	10,00 (30)(10,00-15,00)	20,31±7,177	20,00 (35)(15,00-25,00)	0,319
RIGHT					
250 Hz	13,97±5,067	15,00(20)(10,00-20,00)	16,25±5,080	15,00(15)(11,25-20,00)	0,084
500 Hz	13,28±5,391	10,00 (20)(10,00 15,00)	14,84±4,664	15,00 (15)(10,00-20,00)	0,45
1000 Hz	12,93±5,264	10,00 (20)(10,00-17,50)	14,53±5,291	15,00 (25)(10,00-20,00)	0,976
2000 Hz	12,59±6,356	10,00 (25)(10,00-15,00)	15,31±6,468	15,00 (25)(10,00-20,00)	0,291
4000 Hz	14,83±7,256	15,00 (30)(10,00-15,00)	20,31±6,832	20,00 (20)(10,00-25,00)	0,095
8000 Hz	14,48±8,166	10,00 (30)(10,00-15,00)	19,38±7,156	20,00 (25)(15,00-25,00)	0,737
LEFT x RIGHT					
250 Hz	13,36±3,911	12,5(12,5)(10-16-25)	16,40±5,496	15(20)(12,5-20)	0,016
500 Hz	13,01±4,550	12,5(17,5)(10-17,5)	14,84±4,874	15(22,5)(10-17,5)	0,071
1000 Hz	11,98±4,972	10(15)(7,5-16,25)	14,53±4,895	15(20)(10-16,87)	0,483
2000 Hz	12,58±5,323	12,5(20)(10-15)	14,68±5,706	15(22,5)(10-17,5)	0,577
4000 Hz	15,34±6,399	15(27,5)(10-17,5)	20,54±5,598	22,5(20)(15-25)	0,025
8000 Hz	14,05±6,892	10(27,5)(10-15)	19,84±6,597	20(27,5)(15-25)	0,684

Table 2. Comparison of the left ear c-VEMP and o-VEMP values between control and bypass groups.

LEFT	Groups				P value
	Control Group		Bypass Group		
	Mean±SD	Median (range) (Q1-Q3)	Mean±SD	Median (range) (Q1-Q3)	
c-VEMP p13 left (ms)	16,10±3,30200	15,67(15,0)(14-17,1)	17,67±4,300	16,67(18,3)(14,5-19,3)	,084*
c-VEMP n23 left (ms)	24,12±3,75591	23,00(13,3)(21,3-25,6)	25,29±4,969	23,67(22,3)(22,3-26,1)	,256*
p13-n23 latency left (ms)	8,01±2,55353	8,67(11,0)(5,66-9,6)	7,62±2,919	6,67(14,0)(5,6-9,3)	,590**
p13-n23 amplitude left (mV)	105,49±70,18127	92,81(258,8)(43,8-161,1)	63,32±37,870	55,70(131,2)(33,2-92,7)	,007**
o-VEMP n10 left (ms)	10,11±,93588	10,00(4,0)(9,5-10,6)	10,77±2,285	10,16(11,0)(9,6-11,4)	,272*
o-VEMP p15 left (ms)	14,98±2,69103	15,00(18,0)(14,3-16,1)	16,15±2,911	16,16(16,6)(14,5-16,8)	,122*
n10-p15 latency left (ms)	5,21±1,43691	5,00(7,0)(4,1-5,8)	5,38±1,391	5,00(5,6)(4,2-6,4)	,672*
n10-p15 amplitude left (mV)	10,19±7,59013	9,17(26,4)(3,7-15,8)	5,59±3,510	4,58(14,7)(3,3-7,1)	,006**

c-VEMP: Cervical vestibular-evoked myogenic potential, o-VMEP: Ocular vestibular-evoked myogenic potential, SD: Standard deviation, ms: millisecond, mV: millivolt, *p-values in bold demonstrate statistical significance.

Table 3. Comparison of the right ear c-VEMP and o-VEMP values between control and bypass groups.

RIGHT	Groups				P value
	Control Group		Bypass Group		
	Mean±SD	Median (range) (Q1-Q3)	Mean±SD	Median (range) (Q1-Q3)	
c-VEMP p13 (ms)	15,58±2,44	14,67(10,3)(14,16-16,33)	17,85±5,274	16,33(16,0)(13,5-22,1)	,040**
c-VEMP n23 (ms)	23,86±2,69	23,33(10,0)(22-24,8)	25,68±4,921	24,67(19,3)(22,1-28)	,085**
p13-n23 latenc(ms)	8,27±2,091	8,00(9,0)(7-9,3)	7,75±1,799	7,67(7,0)(6,1-8,83)	,317**
p13-n23amplitude (mV)	113,31±62,015	104,3(235,9)(65,2-104,3)	73,77±54,436	54,65(197,4)(27,4-103,5)	,013**
o-VEMP n10 right (ms)	9,9±0,933	9,67(4,3)(9,33-10,3)	11,12±2,746	10,50(14,6)(9,67-11,4)	,006*
o-VEMP p15 right (ms)	14,81±0,901	14,67(4,0)(14,16-15,1)	16,28±2,854	15,67(14,6)(14,6-16,4)	,005*
n10-p15 latency right (ms)	4,9±0,781	4,67(3,3)(4,33-5,16)	5,15±1,208	4,67(4,3)(4,33-5,67)	,791*
n10-p15 amplitude right (mV)	9,53±7,189	8,19(30,5)(3,71-14,26)	4,73±4,186	3,67(17,9)(1,85-5,62)	,005*

c-VEMP: Cervical vestibular-evoked myogenic potential, o-VMEP: Ocular vestibular-evoked myogenic potential, SD: Standard deviation, ms: millisecond, mV: millivolt, *p-values in bold demonstrate statistical significance.

group, the p13-n23 amplitude was lower in the bypass group and the differentiation was numerically significant (p=0,013) (Table 2) (Figures 1,2, 3).

In the c-VEMP outcomes for the left ear, we detected a numerical significance in p13-n23 amplitude (p= 0.007) and the average amplitude of p13-n23 declined in the bypass group (63,32 ±37,87) (Table 3).

Using the o-VEMP test, p15, n10, n10-p15 latency, and the amplitude of n10-p15 were examined. In the o-VEMP results of the left ear, we detected a numerical significance in the amplitude of n10-p15 (p = 0.006) between the groups. The mean n10-p15 amplitude value was 5,59±3,51 in the bypass group, which was lower than in controls (Table 3) (Figures 1,2, 3).

In the right ear o-VEMP, the average n10-p15 amplitude was 4,73±4,18 mv in the bypass group, which was lower than in controls, and the differentiation was numerically significant (p = 0,005). The mean n10 latency was 11,12±2,74 ms in the bypass group and greater than in controls, the difference was numerically significant (p=0,006). Similarly, the mean p15 latency was 16,28±2,85 in the bypass group, and this value was higher than in controls. The comparison showed statistical significance (p= 0,005) (Table 2) (Figures 1, 2, 3).

The cVEMP asymmetry rate of a total of 4 cases could not be calculated. The ssymmetry rate of 24 cases was found to be higher than 19.23%. None of the participants showed pathological results in the Dix-Hallpike test.

Discussion

Our results suggest that the on-pump CABG procedure may affect the audiovestibular system. While all frequencies were detected in normal ratio, a numerical significance was determined at 250 (p= 0,013), 500 (p=0,045), 2000 (p=0,028) and 4000 (p=0,045) Hz for the comparisons of left ears between groups. The average values for all frequencies were higher in the bypass group. According to the outcomes of the right ear c-VEMP, p13 (p = 0.040) was significantly differentiated between the groups. The p13 latency was higher than in the control group, and the p13-n23 amplitude was lower in the bypass group, and the differentiation was numerically significant (p=0,013). In the left ear c-VEMP outcomes, we detected a numerical significance in p13-n23 amplitude (p= 0.007) between the groups. The average amplitude of p13-n23 declined in the bypass group. In the analysis of the o-VEMP of the left ear, we detected a numerical significance in the amplitude of n10-p15 (p = 0.006) between the groups. The mean n10-p15 amplitude value was lower than in controls. On the other hand, in the right ear o-VEMP outcomes, the average n10-p15 amplitude was lower than in controls (p = 0,005). Mean n10 latency was greater in the bypass group (p=0,006). Similarly, mean p15 latency was high in the bypass patients and the comparison showed statistical significance (p= 0,005).

The otolith task is measured via VEMP test batteries as a reaction to a great intensity acoustic stimuli. Bilateral or unilateral lack of o-VEMPs is likely to demonstrate either utricular defective functions or a pathology in the superior vestibular nerve, extraocular muscles or their centrical communication [12]. We could not obtain o-VEMP responses from 12.9 % of our patients. Additionally declined p13/n23 (c-VEMP) amplitudes may indicate defective functions or pathologies. Also, the lack of c-VEMPs in nearly 6.4% of our patients and declined amplitudes are likely to indicate the presence of pathologies of the inferior vestibular nerve, saccular, or their central contacts. Walsted et al. reported that four patients developed severe left-sided SSNHL following CSWEC [9]. Although SSNHL caused by the use of gentamicin during the procedure has been reported in the literature, gentamicin was not used in any of our patients. In addition, perioperative cerebral hypoperfusion is an important agent that may play a critical role in SSNHL. The most common explanation of SSNHL following CSWEC appears to be the obstruction of the cochlear division of the internal auditory artery due to microembolisms. This may be due to fragments from calcified and/or arteriosclerotic plaques, air or fat. This mechanism is indicated in past studies demonstrating that cerebral injury due to embolism may be a complication of cardiac surgeries [9]. Although we included patients with normal hearing in this clinical study, we detected that many frequencies were higher in the bypass group in comparison with the controls. Research has indicated an increased vulnerability in males to the occurrence of higher tone injury. According to the male predominance, with an increased rate of basilar artery atherosclerosis, perfusion insufficiency and common longer pump periods appear to be the most frequent reasons for the uncommon causes of hearing impairment after cardiopulmonary bypass surgical procedure [15]. Various studies have been reported, including both irreversible and reversible hearing loss after cardiac bypass procedure. According to the prospective-controlled survey, it was indicated that mild alterations could develop in the high frequencies and researchers underlined that four cases developed an evident decrease in hearing thresholds. In their study, the control group consisted of open thoracotomy free from extra-corporeal cycle and a research group of CABG cases on extra-corporeal bypass [16-17]. Other suggested outcomes of SSNHL include occlusion of cochlear artery, intracochlear membrane ruptures, and insufficiency of the endocochlear potential. Some studies underlined the negative effects of nitrous oxide used in anesthesia induction on the middle and/ or inner ear [18-19]. Due to the age-provoked alterations in the central nervous and peripheral auditory system and in the vascular mechanism may also affect the auditory dysfunction. Considering this factor, we designed a relatively young patient group who had undergone CABG procedure [20]. Vestibular deterioration was reported to be 70 % higher in participants with diabetes mellitus [21]. Li et al. reported that they could not find a significant association between cardiovascular risk factors between VEMP responses and characteristics of VEMPs [22]. Although there are publications showing that diabetes mellitus and other cardiovascular risk factors have an effect on VEMP measurements, there are publications indicating that it has no effect, and we did not include diabetic patients in our study. VEMP tests constitute a considerable part as a part of vestibulometric analysis and are utilized to detect the utricular and saccular functions. The o-VEMP measures the complete superior vestibular nerve and utricular functions and on the other hand, c-VEMP allows assessment of the integrity of the inferior vestibular nerve and as well as the saccule. The prolongation of the positive peak, the rise in latency or the lower amplitude are the markers of pathological c-VEMP and are accepted as signs of the saccular defect [23].

It may not be sufficient to evaluate the vestibular system with VEMP tests solely. We know that VEMP tests are complementary tests. However, in the conditions of our clinic, we used it because the only test battery we had was the VEMP test.

In case of changing the results of VEMP tests, we included patients who were relatively young and had no additional disease other than bypass. These features challenged us and we were able to find a few patients that fit this schedule. It would be appropriate to support the results of our study with larger patient groups in the future.

Conclusion

Consequently, it is possible to mention that the CBAG may affect balance-connected mechanisms at varied levels and intensity. We could not find a similar type of study in the literature to compare the outcomes of our study. We think that this is a feature that makes our work superior.

Scientific Responsibility Statement

The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

Animal and human rights statement

All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. No animal or human studies were carried out by the authors for this article.

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Conflict of interest

None of the authors received any type of financial support that could be considered potential conflict of interest regarding the manuscript or its submission.

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